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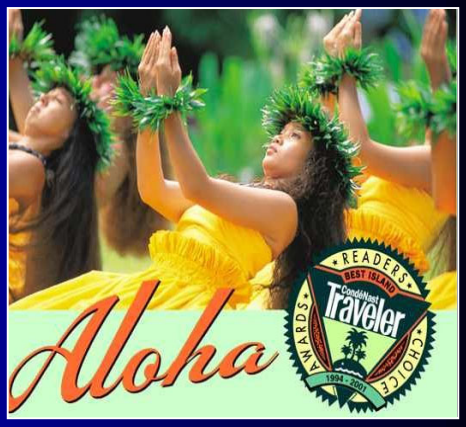
Energy Benchmarking Studies in Hawaii

Rebuild America Peer Exchange Meeting

March, 2003



By Thomas D. Van Liew

Hawaiian Electric Company & Rebuild Hawaii

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Agenda

- **Define Benchmarking.**
- **The Uses of Benchmarking.**
- **Benchmarking studies in Hawaii (Humid Climates).**
- **Energy Analysis Methods using Energy Benchmarking.**
- **Benchmarking in the Pacific NW Region – BPA ELCAP Studies.**
- **Other Benchmarking Studies and Resources: Snohomish County School District, PGE, ASHRAE, EPRI, LBL, and EPA.**

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What is Energy Benchmarking

- Energy Benchmarking is a relatively simple , low-cost method for evaluating a buildings energy performance.
- Benchmarks are commonly used in other industries like GNP, economic performance, miles/gallon.
- It is a usable way to quantify building energy use in terms of energy intensity (units of energy per square foot per year). It compares annual energy consumption on a square footage basis.

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Benefits of Energy Benchmarking

Allows facility Mangers to sort buildings into classes.

Assists owners in identifying how energy efficient their buildings are relative to each other, competitors and national averages.

It provides a method to determine if a particular building is a good candidate for energy efficiency improvements.

Can provide general idea if energy conservation measures are worth investigating and provides rough payback period.

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Factors That Effect Benchmarking

- **Equipment operation**
- **Occupant Behavior (thermostat settings, etc.)**
- **Operating hours**
- **Number of Occupants**
- **Climate**
- **End-uses (cooking, water heating, refrigeration)**
- **Fuel choices**

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Energy Benchmarking - Units

Annual energy usage per square-foot.

Energy Utilization Index (EUI) – A benchmark normally used to measure the effectiveness of building energy efficiency. It is measured in kWh/sq.ft.-year or kBtus/sq.ft.-year.

All electric:	**kWh/sq.ft-year**
Total Building:	**kBtus/sq.ft-year**

Add all energy usage and divide by building square footage. Building square footage is normally defined as "conditioned" square footage.

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Energy Benchmarking

- **Step 1 –** Calculate the facility energy usage (annual) and determine kWh/sq.ft.-year or kBtus/sq.ft.-year based upon "conditioned square footage". **Compute:** Kwh/sq.ft.-year = Total Energy (kWh/year)/square footage.
- **Step 2 –** Select comparisons – Best to compare buildings of similar types.
- **Step 3 -** Draw conclusions. Prioritize projects and capital investments.

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Hawaii Climate Conditions

- **Hawaii is a cooling only climate. Space heating is not required. (0 heating degree days).**
- **Air conditioning is year round and considered a tropical humid climate.**
- **Weather is typically 82/66 in the winter and 88/72 in the summer. Humidity levels are between 50 and 75%.**

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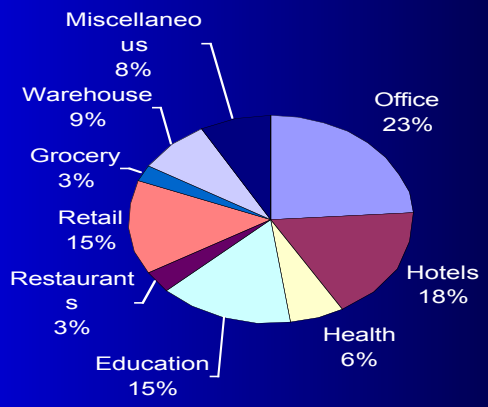
Hawaii Commercial Market

Floor Space, Total = 173 Million Square Feet



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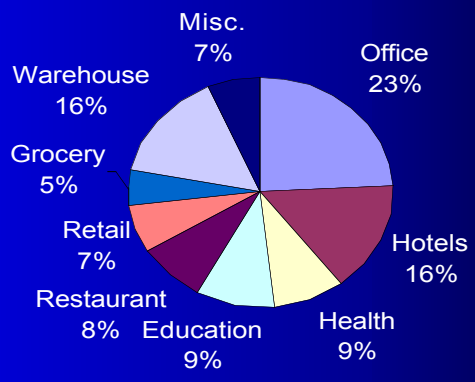
Hawaii Commercial Market

Electric Sales, Total = 2,800 GWhs



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Maui Schools Benchmarking Project

- As part of the Rebuild Hawaii and Energy Smart Schools program, thirty two (32) schools were audited to benchmark energy consumption and determine potential for energy savings of lighting conversions.

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Maui Schools Benchmarking Study

Thirty two (32) schools were audited and evaluated and school Population ranged from 3 to 1,709 students.

The size ranged from 3,770-176,292 square feet. Average square footage = 62,358.

Energy Usage: Energy usage in the schools varied with building size, population, operating hours and types of equipment.

Energy usage ranged from:
24,128 – 1,302,000 kWh/year with an average of 375,805 kWh/year

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Maui Schools Benchmarking Study

Operating Costs – Operating costs varied with the size of the school, operating hours and electric rate schedules. They ranged from $4,750 to $229,454 per year with an average of $72,367 per year. This is equivalent to $0.60 to $2.16 per square-foot per year.

Electric Rates - varied from 17.6 to 27.1 cents per kwh (electric rates include service, demand, energy and fuel cost adjustment charges). Distant Islands (Molokai) had the highest electric rates.

EUI's ranged from:
3.05 to 11.52 kWh/sq. ft. – year or
10.4 – 39.3 kBtus/sq.ft.-year.

Average = 5.9 kWh/sq. ft. –year (about _ of a typical office High rise in Hawaii).

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Maui Schools Lighting Audits

In addition to the Benchmarking Study, lighting energy audits were conducted on each school to determine the potential energy savings from converting standard T12 lamps/magnetic ballasts to T8 lamps/electronic ballasts.

Energy savings from these audits indicated substantial energy savings could be obtained through lighting conversions. Energy savings ranged from:

* **$243 – $30,729 per year.**
* **Paybacks ranged 2.4 to 12.7 years.**
* **Lighting loads varied from 13-85%.**

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Maui Schools Project Interesting Observations

- **Largest schools: M**aui HS and Baldwin HS are being implemented first with T8s, (biggest bang for the buck) and show the greatest potential for energy savings and greatest population to effect.
- **Molokai:** Electric rates are 27% higher than that of Maui.
- **A/C:** Those schools with A/C have the highest EUIs but not necessarily the most cost effective ECMs (lighting is already T8s on new schools).
- **Operating Hours:** Schools with the longest operating hours have the shortest payback periods.
- **Energy Savings Potential:** The total electric energy consumption from converting to T8s is about 1,837,827 kWh/year or $369,587 with an average payback of 5.7 years.

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Energy Benchmarking of Commercial Buildings

- **Energy Benchmarking studies were also conducted on other commercial sectors including offices, grocery stores, hotels, restaurants, schools, etc.**
- **Detailed customer data was gathered by Regional Economic Research, Inc who conducted field studies (256 sites) , customer response surveys (861 sites) and Performed HVAC energy analysis using DOE 2.1E. EUIs, End-Use loads and Load Shapes were determined from the results of the computer simulations.**

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EUIs by Commercial Sector

- **Offices**
- 22.82 kWh/sq.ft-year
- **Lodging**
- 16.14 kWh/sq.ft.year
- **Restaurants**
- 52.88 kWh/sq.ft.-year
- **Grocery Store**
- 53.05 kWh/sq.ft.-year
- **Education**
- 9.00 kWh/sq.ft-year
- **University of Hawaii**
- 13.82 kWh/sq.ft.-year
- **Health Care**
- 24.83 kWh/sq.ft-year
- **Retail**
- 25.50 kWh/sq.ft.year
- **Apartments**
- **10.11 kWh/sq.ft.-year**
- **Warehouse**
- 6.76 kWh/sq.ft.-year
- **Miscellaneous**
- 12.09 kWh/sq.ft.-year

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"Enhanced" EUIs by Commercial Sector

- **A more detailed database was established to determine EUIs by commercial sector as well as target markets. For Example, not only were grocery stores identified, but similar types of grocery stores of similar size and operational characteristics. From this data the "enhanced" EUIs were established with End-Use Loads.**

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Enhanced EUIs

- **Offices** – 22.8 kWh/sq. ft. year (22 buildings).
- **Condos** – 14.4 kWh.sq.ft-year (11 facilities)
- **Hotels** – 22.7 kWh/sq.ft.-year (16 locations)
- **Grocery Stores** – 70.5 KWh/sq.ft-year (10 locations)
- **Bank** - Branch Offices – 20.0 kWh/sq.ft.-year (49 locations).
- See HECO End-Use Pie Charts for more details.

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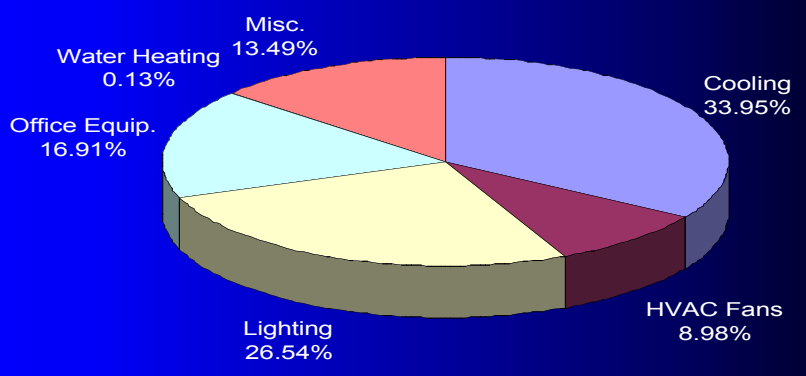
Typical Office Building
End-Use Energy
Tropical Climate – Hawaii
EUI = 22.8 kWh/sq.ft.-year



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Observation of EUIs in Office Buildings

- **Why such a difference in Energy Usage?**

The are many factors which contribute to the EUI including: equipment operation, occupant behavior, operating hours, number of occupants, climate, end-uses, O&M practices and equipment efficiencies.

Of the list of 22 offices studied, the major characteristics which contributed to the variance in the EUIs were: age of building, HVAC type, lighting type, and size. The building age (no A/C before 1950), HVAC type (constant Volume, dual duct, Heat pump, VAV, water cooled versus air cooled chillers, package equipment, etc.), insulations levels, lighting (T12 vs. T8s) and owner innovativeness all **can effect building energy efficiency.**

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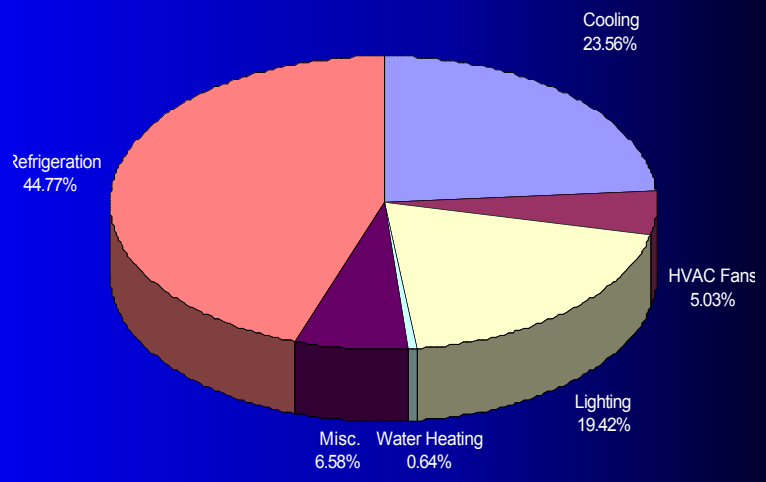
Typical Grocery Store
End-Use Energy
Tropical Climate – Hawaii
EUI = 70.5 kWh/sq.ft.-year



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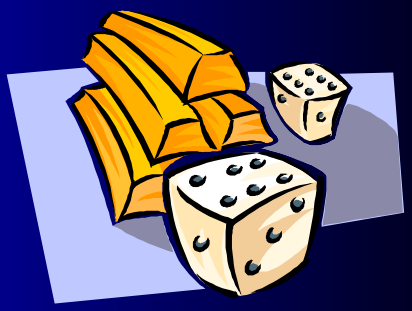
EUIs in Grocery Stores

- Four grocery stores from each major chain were audited by a Independent Engineering Consultant (Hatten/Johnson and Associates - Portland). Actual Energy Usage and End-Uses Vary Considerably between grocery stores.



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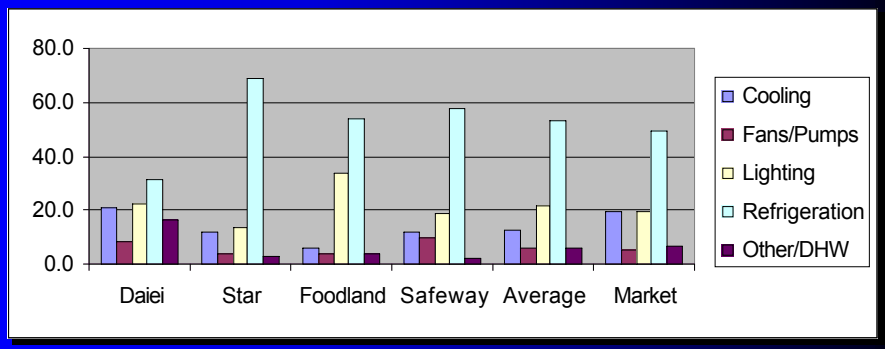
Grocery Store End-Uses

Average EUI = 70.9 kWh/sq.ft/-year



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Bank Offices
Tropical Climate – Hawaii
EUI Average = 20.07 kWh/sq.ft.-year

Forty Nine (49) Bank Branches were evaluated.

Square footage: varies from 870 to 37,750 sq. ft. with an average of 7,238 sq. ft.

Energy usage: varies from 18,296 to 887,767 kWh/year with an average of 142,767 kWh/year.

EUI's: 7.96-36.40 with and average of 20.07 kwh/sq.ft.-year (68.5 kBtus/sq.ft.-year).

Reasons for variance: Age of the facilities, size, customer counts, operating hours, computer technology, HVAC and lighting system types, efficiency and controls.

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Other Facilities – Restaurants
Tropical Climate – Hawaii

- **Restaurants - EUIs vary depending upon:**
- **Type of restaurant,** "sit down versus fast food", number of meals served, type of dishes washed.
- **EUIs: Fast Food** – McDonalds - 86.6 kWh/sq.ft-year
- **Full Service**- Zippy's- 75.5 kWh/sq.ft.year.
- **Type of water heating, cooking and HVAC energy sources.**
- **Building Size –** Square footage.
- **O&M of equipment.**

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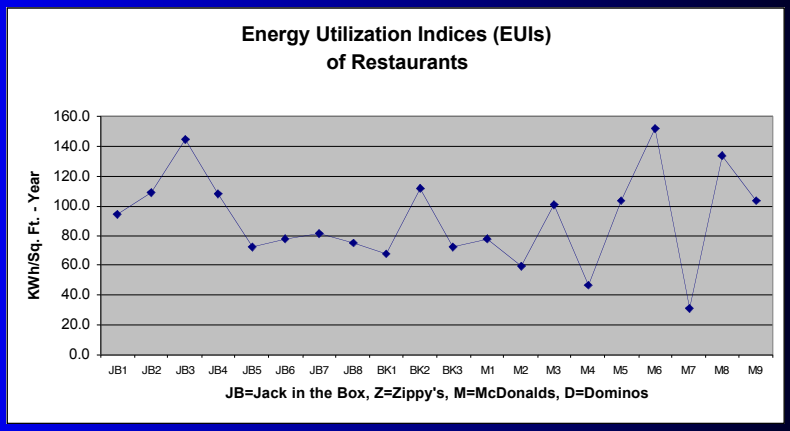
Fast Food Restaurant EUIs



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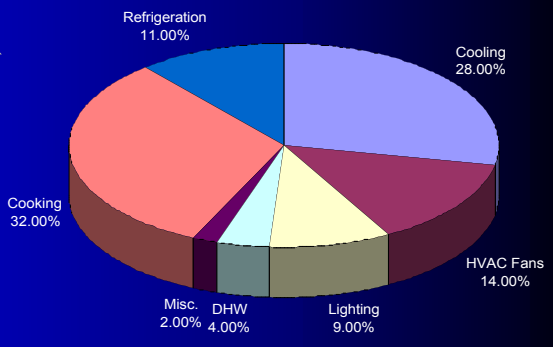
Typical End-Use Energy at McDonalds Restaurant 154.2 kWh/sq.ft.-year



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How Can Benchmarking Assist in Energy Analysis?

- Provides relative differences in energy usage between same types of buildings.
- Provides method to prioritize resources and budgets based on outcome of Benchmarking process.
- Identifies low hanging fruit.
- Provides method to determine approximate energy savings of ECMS.

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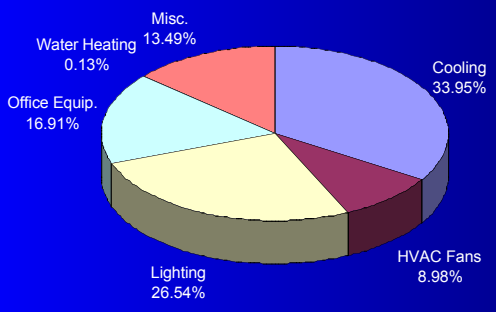
Using Energy Benchmarking and End-Use Energy to Predict Energy Savings



Say a new HVAC system is 15% more effect than existing system.

Then Energy savings=

20.8 kWh/sq.ft-year

- *10,000 sq. ft.
- *.33 (33%)
- * .15 (15) =
- 10,296 kWh/year or $1,296/per year.

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Determining Approximate Payback

10,000 square feet

25-ton system

1.3 kW/ton

15% more costs (marginal based on first cost differences).

SP = ($200/ton*25tons)/$1,296

SP = 3.9 years.

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Other Studies In Energy Benchmarking

* BPA ELCAP
* RCMs
* PGE
* EPRI
* ASHRAE
* EPA/Energy Star
* Oakridge National Labs

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Energy Benchmarking in the Pacific NW - BPA ELCAP Study

- BPA determined end-uses and energy performance of different buildings by sector.
- The study conducted by SBA Consulting for BPA is known as the "Commercial ELCAP Study".

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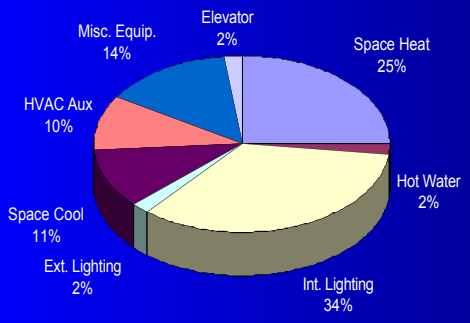
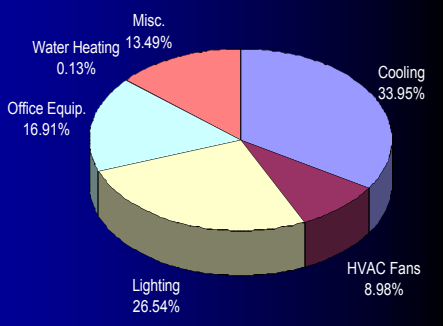
Office Buildings

(EUIs in kWh/sq.ft.-year)

- BPA ELCAP
- EUI = 21.6



- HECO
- EUI = 22.8



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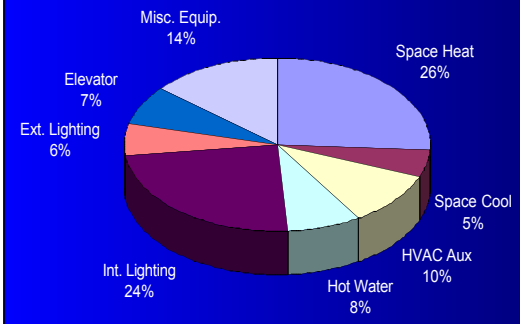
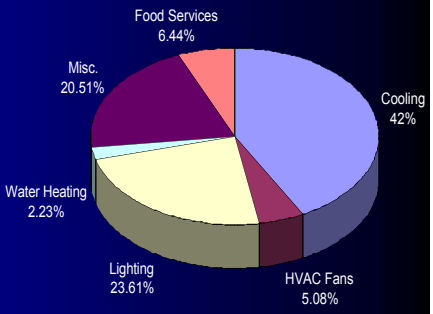
Hotel Facilities

(EUIs in kWh/sq.ft.-year)

- **BPA ELCAP**
- **EUI = 24.3**



- **HECO**
- **EUI = 22.7**



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Snohomish School District

(Data provided by Ray Burton – RCM)

156 Schools Analyzed:

101 Elementary, 32 Middle and 23 High Schools

Electric and Gas heated.

EUIs:

Grade: 1.8-19.5, Ave. = 8.5 kWh/sq.ft.-year

Middle: 5.1-19.49, Ave. = 9.5 kWh/sq.ft.-year

High: 5.2-21.7, Ave. = 10.1 kWh/sq.ft-year.

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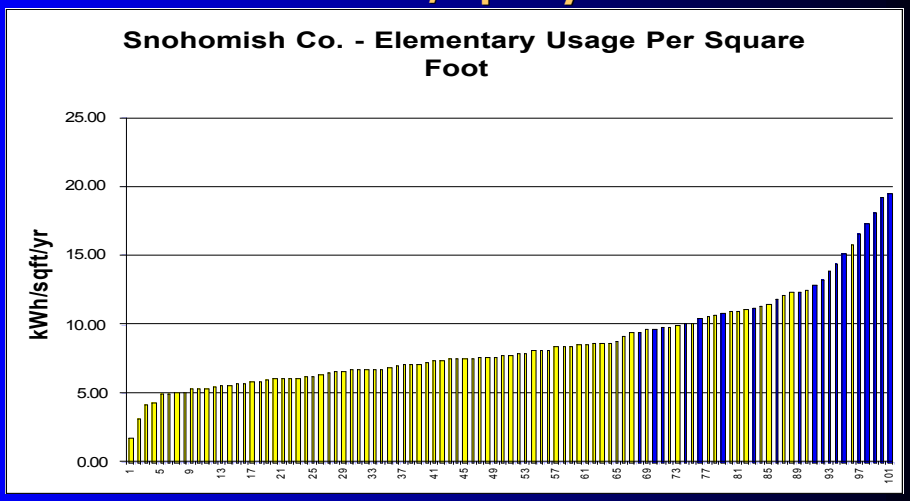
Snohomish School District
Elementary Schools
8.5 kWh/sq.ft.-year



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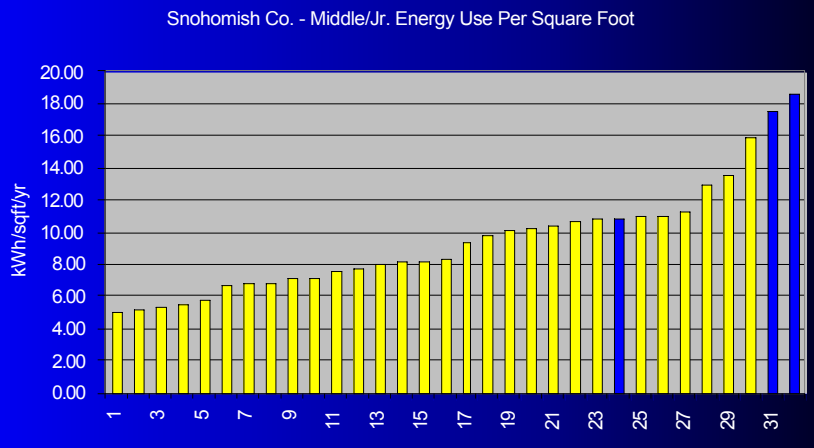
Snohomish School District
Middle Schools
9.5 kWh/sq.ft.-year



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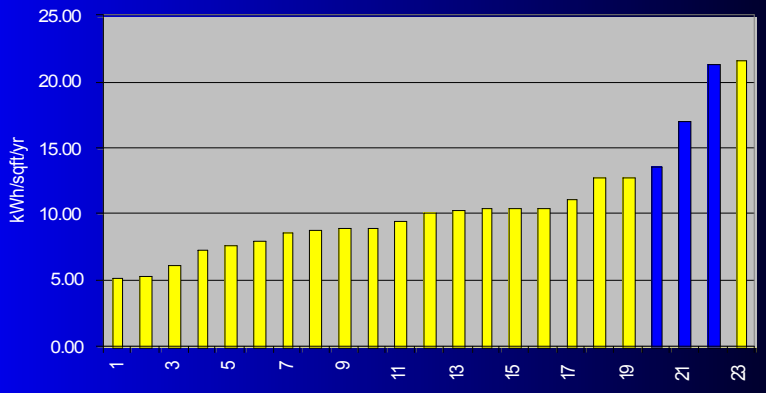
Snohomish School District
High Schools
10.2 kWh/sq.ft.-year



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Portland General Electric
ALL Electric Building EUIs

Portland General Electric (PGE) did a number of Energy Benchmarking studies to promote all electric buildings in the 70s.

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PGE ALL-Electric Building EUIs

Office Buildings -1
22 Sites from 1,000-42,000 sq.ft.
21.7 kWh/sq.ft-yr.

Office Buildings- 2
38 Sites from 800-125,000 sq.ft.
20.7 kWh/sq.ft-yr.

Restaurants
14 Sites from 900-7,250 sq.ft.
89.7 kWh/sq.ft-yr.

Retail
28 Sites from 1,200-62,470 sq.ft.
35.5 kWh/sq.ft-yr.

Schools
22 Sites from 1,000-42,000 sq.ft.
21.7 kWh/sq.ft-yr.

Grocery Stores
18 Sites from 11,700-45,000 sq.ft.
72.7 kWh/sq.ft-yr.

Churches
16 Sites from 2,400-7,500 sq.ft.
10.5 kWh/sq.ft-yr.

Nursing Homes
10 Sites from 1,050-52,4888 q.ft.
33.1 kWh/sq.ft-yr.

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ASHRAE Benchmarking Database (All Numbers in kWh/sq.ft.-year)

Offices	18.9
Lodging	15.2
Grocery	54.1
Restaurant	36.0
Health Care	26.5
Warehouse	6.4
Education	8.4
Retail	11.8

TC 9.6 Systems Energy Utilization

Kenneth Gillespie
925-866-5329
Klg2@pge.com

"Benchmarking of Building Energy Performance Rating Protocols".

1999 ASHRAE HVAC Applications Handbook - Chapter 34.

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EPRI

The Electric Power Research Institute (EPRI) has done a benchmarking analysis by US region.

The EPRI data was collected from the National Energy DataMart report. The most recent survey was conducted by DOE in 1995 on over 6000 commercial buildings.

Commercial Building Energy Consumption Survey (CBECS).

10 Regions including Pacific NW (Oregon, WA) and Pacific SW (Hawaii).

EPRI data not all that useful for Hawaii – Tropical Climate.

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EPRI Benchmarking Database

PNW = Pacific NW, PSW= Pacific SW
(All Numbers are EUIs in kWh/sq.ft.-year)

Small offices	PNW–17.49/PSW–15.09
Large Offices	*PNW–20.34/PSW–23.94*
Restaurants	PNW–33.74/PSW–30.06
Retail	PNW–12.97/PSW–11.02
Grocery	PNW–50.62/PSW–43.55
Ref- Warehouse	PNW–26.09/PSW–22.64
Warehouses	PNW–6.18/PSW–5.34
Schools	PNW–8.58/PSW–7.42
Colleges	PNW–15.33/PSW–13.04
Hospitals	PNW–32.67/PSW–23.94
Nursing Homes	PNW–16.24/PSW–13.60
Lodging	PNW-12.56/PSW-10.90

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Other Sources

EPA Energy Star Program

Energystarbuildings@epa.gov

1-888-star yes

Oak Ridge National Laboratory

"Benchmark Your Building"

http://eber.ed.ornl.gov/benchmark

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Summary

- Energy Benchmarking is a useful tool to rate building's and energy performance.
- Allows Facility Managers and Energy Analysts to determine relative energy efficiency of different classes of buildings helps to determine potential energy savings.
- Identifies how to prioritize projects and determine where money should be spent for energy improvements.
- Can be used to estimated potential energy savings and cost-effectiveness of ECMs.